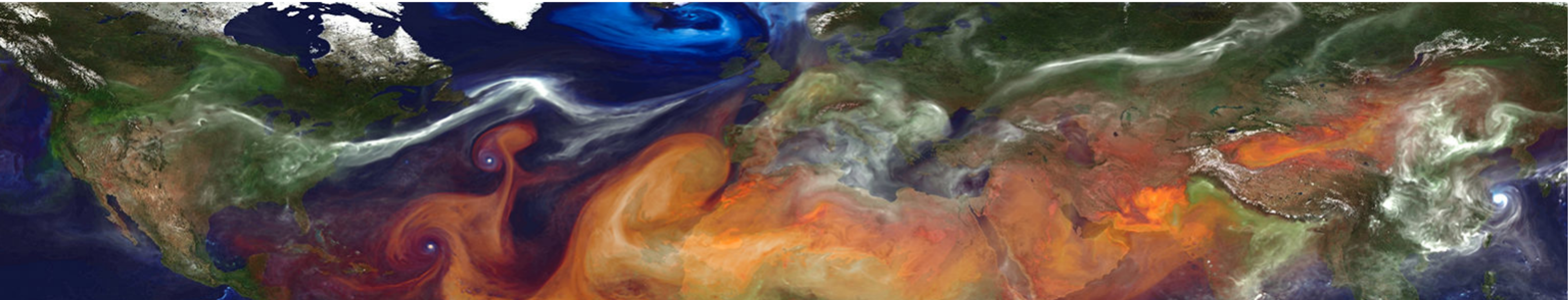
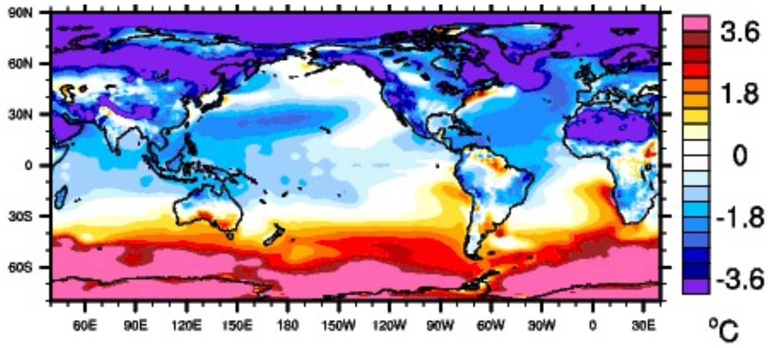
A glimpse into the ongoing climate prediction activities with EC-Earth: **going beyond CMIP6**

Pablo Ortega (BSC)
On behalf of the Climate Prediction Working Group

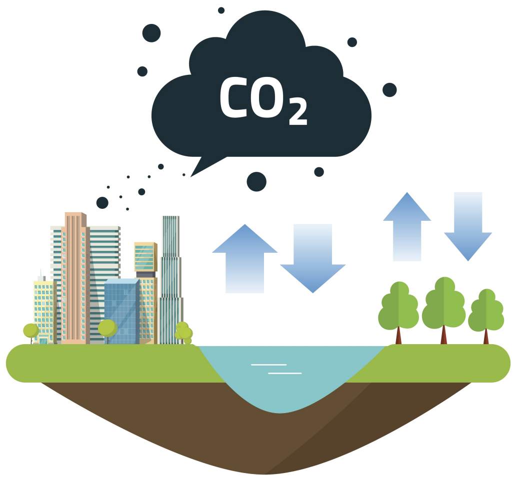
EC-Earth meeting, Lund, 11-13 October 2022



A joint effort to expand the predictive capabilities of EC-Earth



- Improving underlying models:
  - Corrected model biases
  - Optimised model tuning
- Enhancing process representation:
  - More realistic forcings (vegetation, aerosol emissions)
  - Increased model resolution
- Enhancing forecast initialization
  - Coupled nudging
  - EnKF assimilation
- Going beyond climate prediction
  - Predicting the carbon cycle
  - Towards marine ecosystem prediction

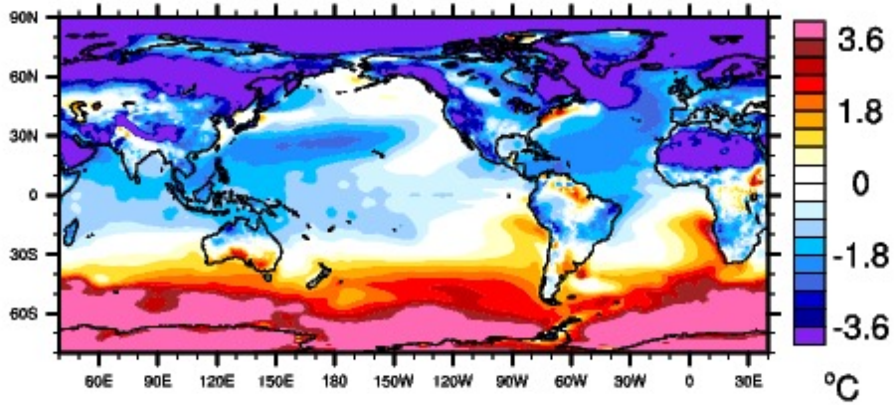


Reducing sea surface biases via climatological flux adjustment

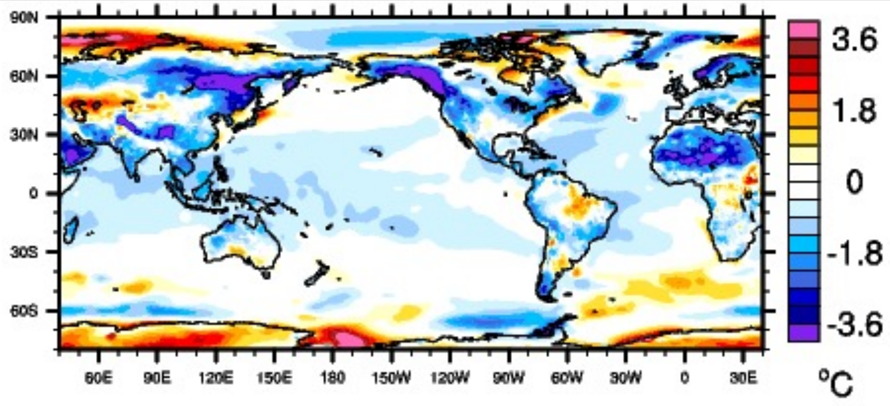
To what extent model biases degrade forecast system skill?

1. Development of a flux adjusted version EC-Earth3-CC with substantially reduced model biases ✓

t2m bias EC-Earth3-CC picontrol



t2m bias EC-Earth3-CC-FA 1990 control



Correction terms in:
SST, SSS, Wind Stress

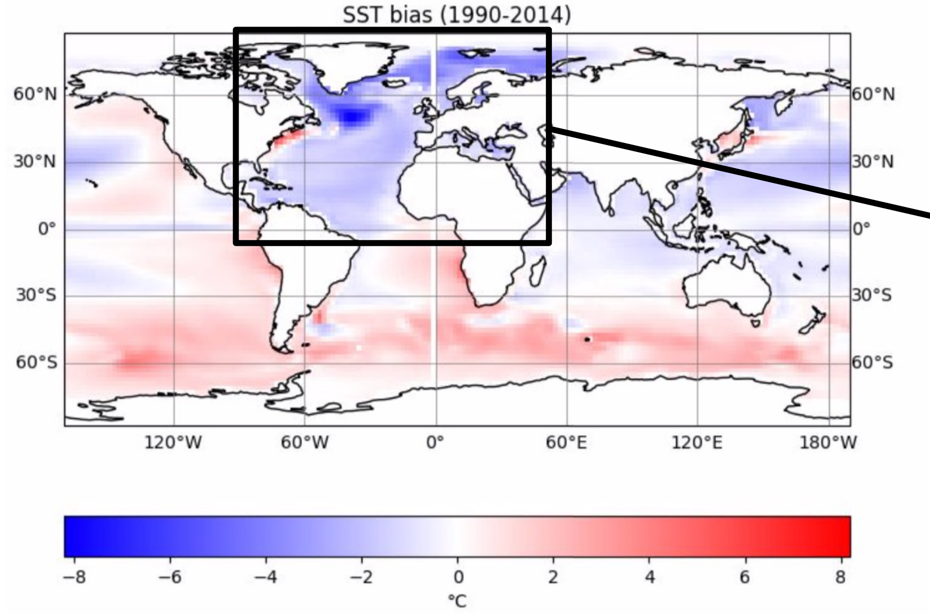
2. Evaluation of EC-Earth3-CC-FA *Ongoing*
3. Production and evaluation of a decadal prediction system with EC-Earth3-CC-FA

Y. Ruprich-Robert

Parameter estimation using the EC-Earth model

Can we reduced key model biases via smart tuning approaches?

SST biases in EC-Earth3 ensemble



The main goal is to update the parameter distribution with new values from a data assimilation system based on an Ensemble Kalman Filter (EnKF)

North Atlantic Focus

But keeping an eye on the impact that the tuning will have elsewhere

Methodology used before the fine tune the sea ice (Massonnet et al 2014)

Main EnKF Equations

$$\mathbf{x}^i_f = \mathbf{M}_i(\mathbf{x}^i_a) \quad (1)$$

$$\mathbf{x}_a = \mathbf{x}_f + \mathbf{K}(\mathbf{d} - \mathbf{H}(\mathbf{x}_f)) \quad (2)$$

$$\mathbf{E}_a = \mathbf{E}_f \mathbf{X}_5 \quad (3)$$

$$\mathbf{E}_{\Theta a} = \mathbf{E}_{\Theta f} \mathbf{X}_5 \quad (4)$$

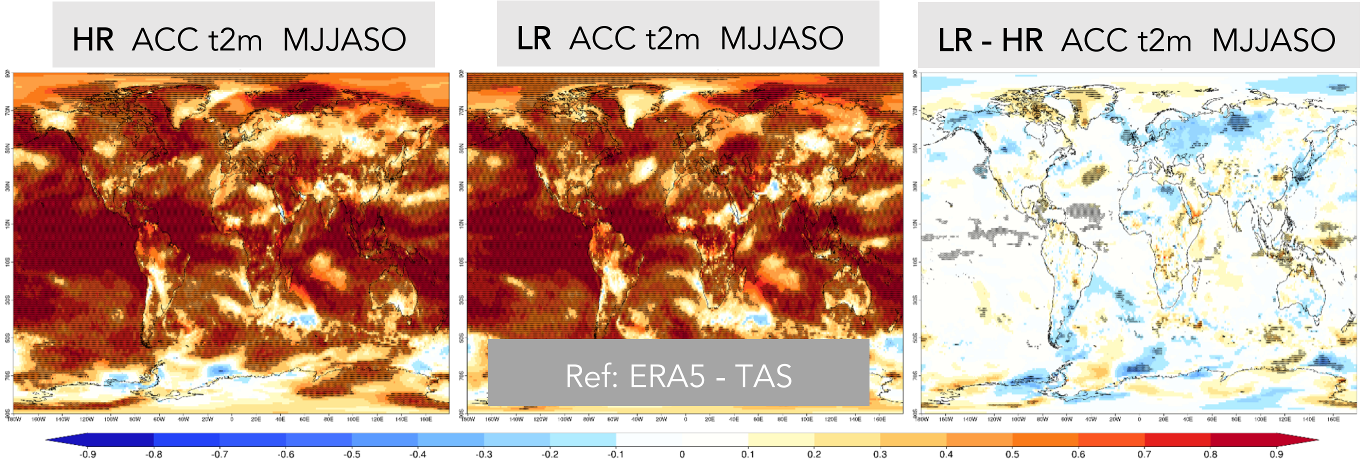
Helena Barbieri de Azevedo, François Massonnet and Xia Lin

Seasonal and multi-annual predictions at eddy-permitting scales

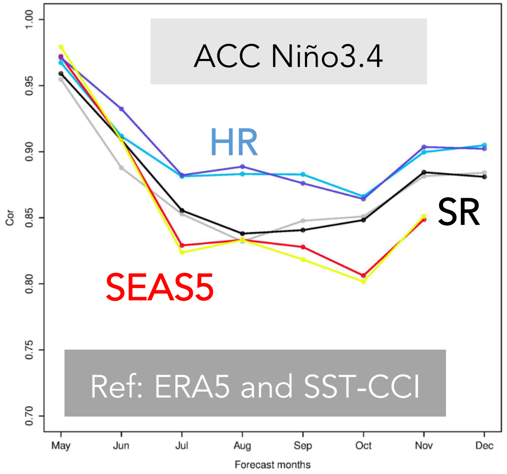
Is there a tangible benefit of increasing the horizontal resolution?

Seasonal forecast system
20 members
23 startdates (1993-2014)
8 forecast months
1st May/ Nov initial dates
Under analysis

Multi-annual forecast system
5 members
31 startdates (1960-2020)
24 forecast months
1st Nov initial dates
In Production



Some 1st May Initialised Examples

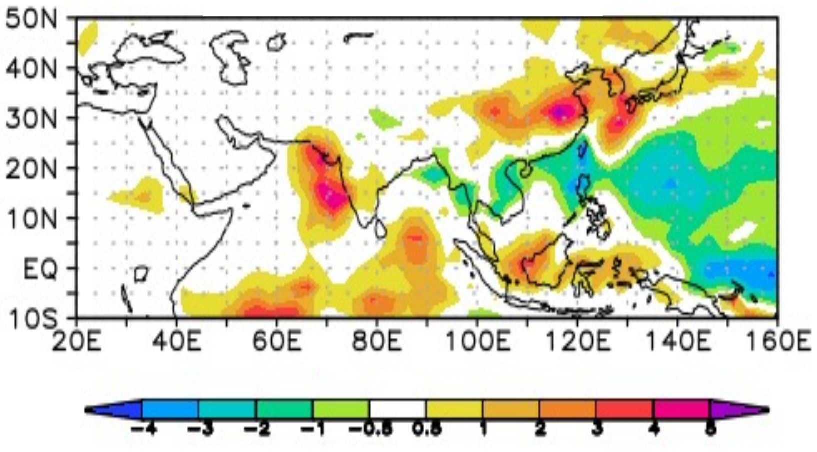


A. Carreric, M. Donat, F. Doblas-Reyes, P. Ortega

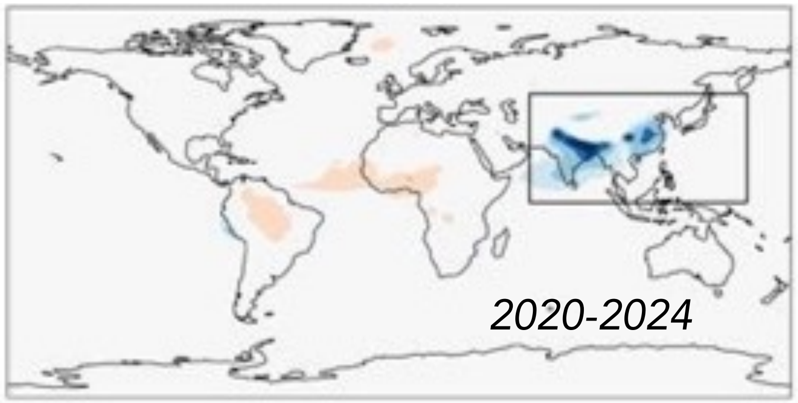
Effects of reduced anthropogenic emissions on the Asian summer monsoon prediction: the case of summer 2020

Can we better predict Asian summer 2020 monsoon with refined emissions?

Precipitation Anomaly JJA 2020



Changes in AOD @550nm



COVID-MIP is based on measures from LeQuere et al (2020)

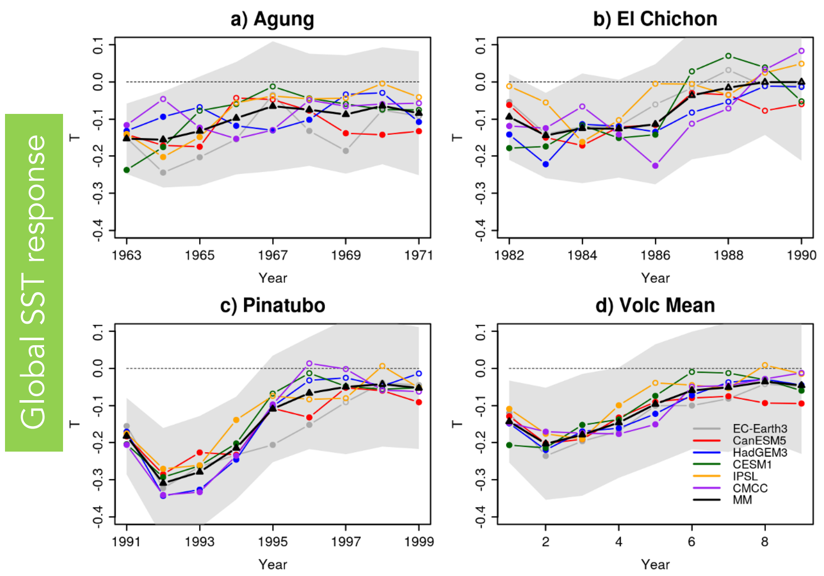
NAME	DATES	START DATE	LENGTH (months)	MEMBERS (#)	ATM forcing (origin)
CLIM	1993-2019	1st May	6	30	HIST+SSP5-4.5
CTRL	2020	1st May	6	60	SSP5-4.5
COVID	2020	1st May	6	60	COVID-19

A. Cherchi, A. Alessandri, E. Tourigny, J.C. Acosta Navarro, P. Ortega, P. Davini, D. Volpi, F. Catalano, T. van Noije, H. Annamalai

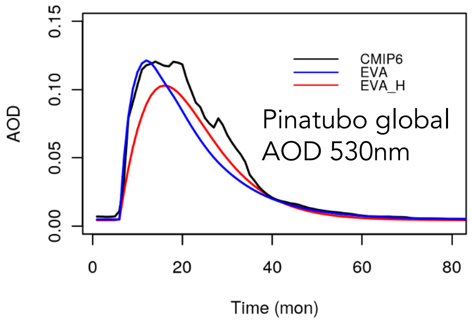
Including the predictive effect of past and new volcanic eruptions

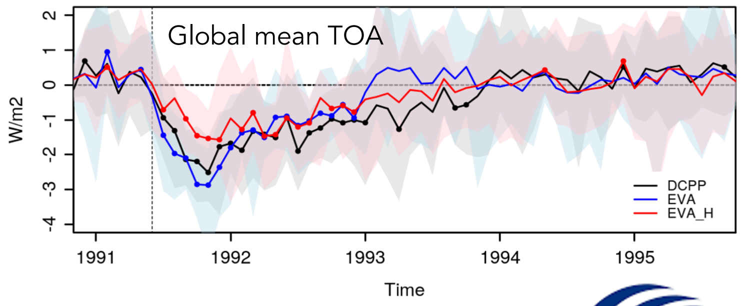
Building and testing the necessary capabilities

- DCPP-C: Climate impacts of major volcanic eruptions in CMIP6 decadal prediction systems (Bilbao et al., in prep.).
- Validating the climate response to idealised volcanic forcings generated with EVA and EVA-H for past eruptions.
- Decadal Prediction Volcanic Response Readiness Exercise (*VolRes-RE*): reapeting Nov 2021 prediction with a large volcanic eruption in April 2022.



Comparing real and idealized aerosol forcings and their responses





R. Bilbao, E. Martín-Martinez, P. Ortega

Effect of improved vegetation-representation on decadal prediction

What are the benefits of considering realistic changes in vegetation?

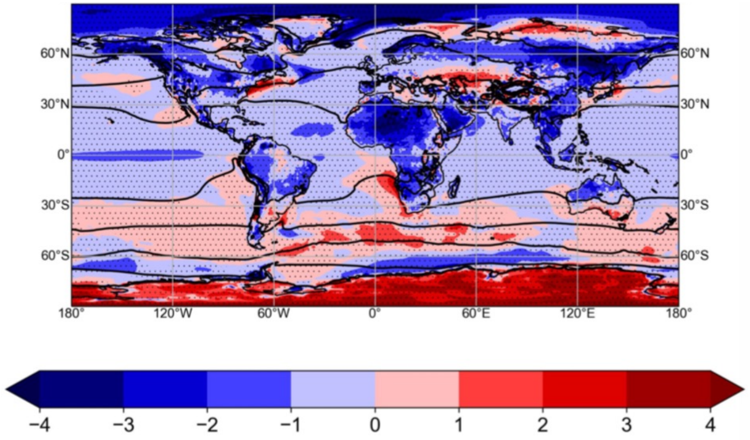
Experimental set-up

- Effective vegetation estimated from satellite data of Fcover, LAI and the ESA-CCI land cover
- Selection of start dates covers the period with available satellite vegetation data (1993-2014)
- Comparison with DCPP r1-10i1f1p1 ensemble (DCPP-CTL)

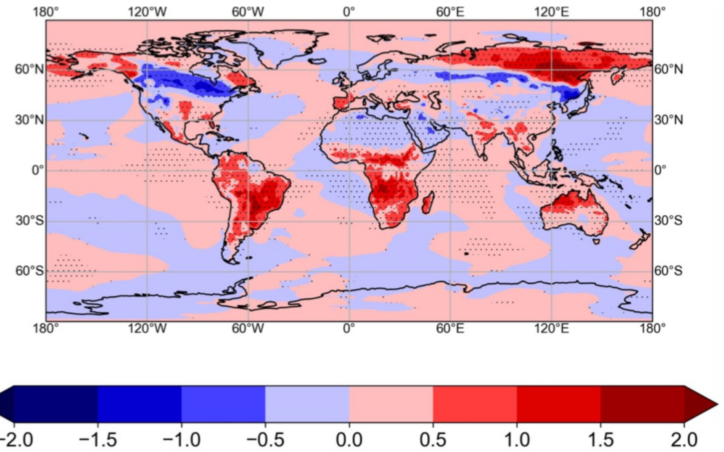
Main results

- Bias is largely reduced in tropical regions (South America and Africa) and Siberia.
- Bias slightly reduced in Indian monsoon region & Australia.
- Regions of boreal forests exhibit a bias increase

DCPPctl bias lead 0



DCPPveg - DCPPctl bias lead 0



E. Di Carlo, A. Alessandri, A. Cherchi, E. Tourigny, R. Bilbao

Common plans for coupled assimilation at DMI & SMHI

Initial Considerations

Current initialization provides limited prediction skill above the uninitialized (historical) runs

Several studies showed the benefit of joint surface & atm. assimilation (e.g., Yang et al, 2021 with GFDL; SMHI experience)

A long continuous assimilation may lead to un-equally "spin-up" length of the ocean states on the course of assimilation

Short assimilation runs have the disadvantage of potential large drifts in the ocean.

Investigating the design of new assimilation approach

Restoring of SST anomalies (HadISST) and surface wind/pressure (ERA5).

Anomalies wrt a moving climatology (30-year before start year).

Test 5-10 yr assimilation runs starting every year vs a long continuous assimilation run.

Length of assimilation decided depending on how deep ocean converges

5-10 member ensemble depending on the resources

New hindcast/forecast experiments

Prediction runs with EC-Earth3 and initial states generated from new assimilation runs

Tests will be done to decide if short or long assimilation runs are finally used

Final details still to be discussed

EC-EARTH T. Tian, A. Drews, M. Devilliers, S. Yang, T. Koenigk and P. Karami SMHI

Towards a simple coupled assimilation approach for decadal prediction

Experimental Protocol

Model version:
EC-Earth 3.3 TL255L91-ORCA1L75

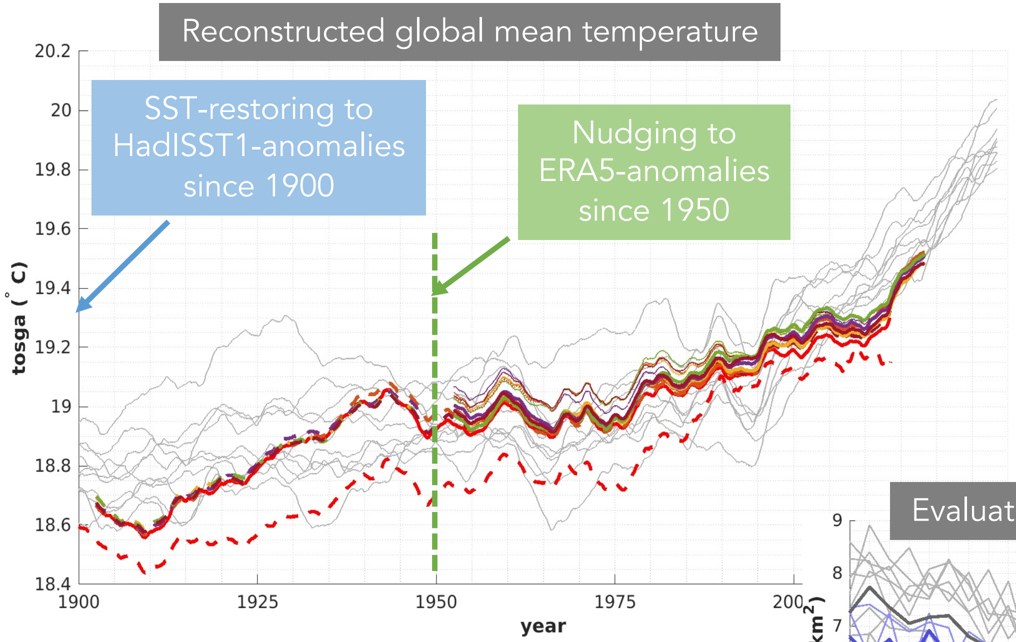
Initialization:
Restarts froom 5 coupled assimilation runs

Data assimilation concept:
Assimilation of surface-near variables

Ocean:
SST-restored to monthly HadISST1 anomalies

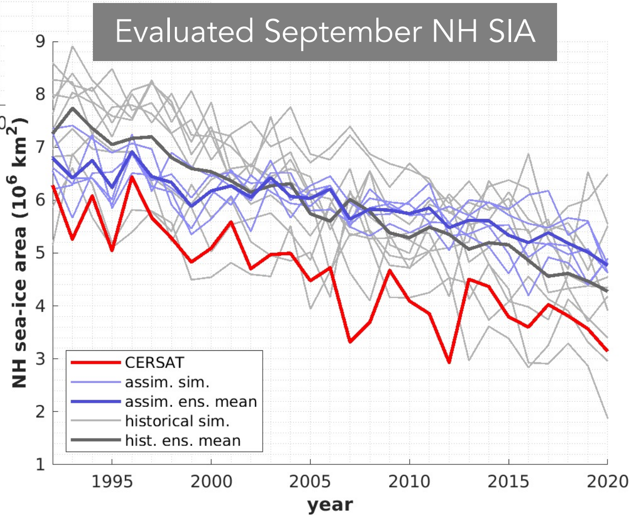
Atmosphere:
Newtonian relaxation towards 6-hourly ERA5 anomalies of relative vorticity and divergence

Obs anomalies from running 31yr-climatologies



Correlation of detrended timeseries:

Assimilation runs:	**0.64**
Historicals runs:	-0.08



T. Kruschke, P. Karami, K. Wyser, U. Fladrich, T. Koenigk

Testing coupled assimilation in a seasonal prediction framework

Set up forecasts

- Initial month: *November*
- Startdates: *1985-2019*
- Length: *10 months*
- 10 members

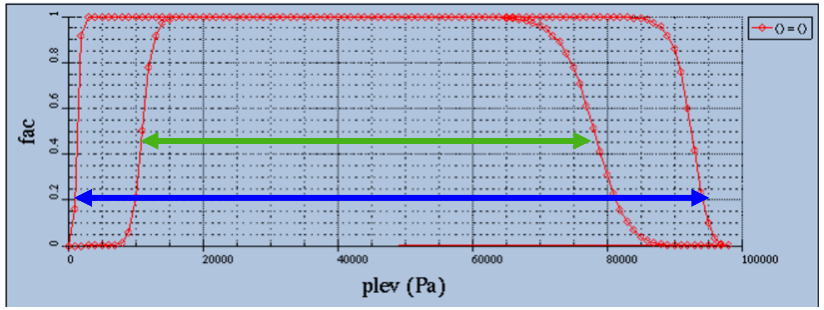
Tested coupled nudging setups

Atm: full column	Oce: standard
Atm: free top-bottom	Oce: standard
Atm: free narrow bottom	Oce: standard
Atm: full column	Oce: no surface
Atm: full column	Oce: weak nudging
Atm: ERA5	Oce: forced recon
SEAS5	

Atmosphere Nudging

ERA5, 12-hour restoring timescale

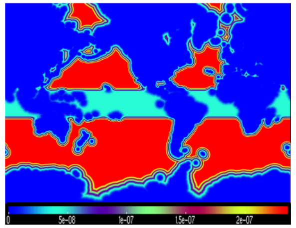
Variables: vorticity, divergence, temperature and log surf pressure)

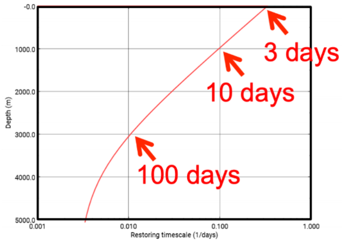


Ocean nudging

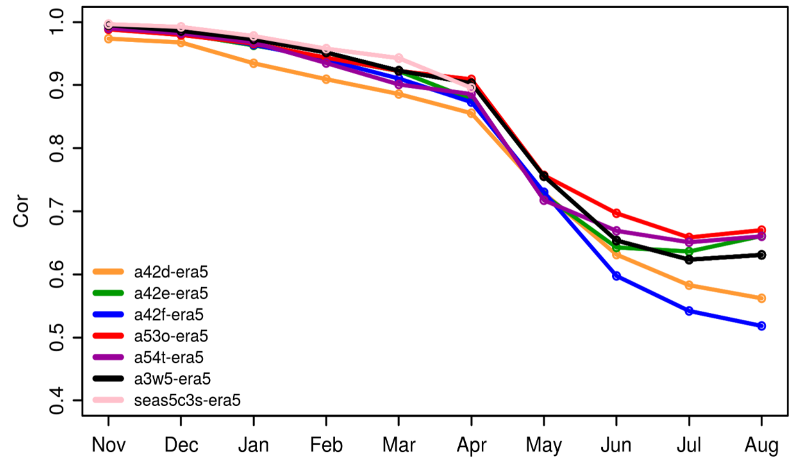
ORAS5, SST and SSS

EN4.2.2 3D T and S

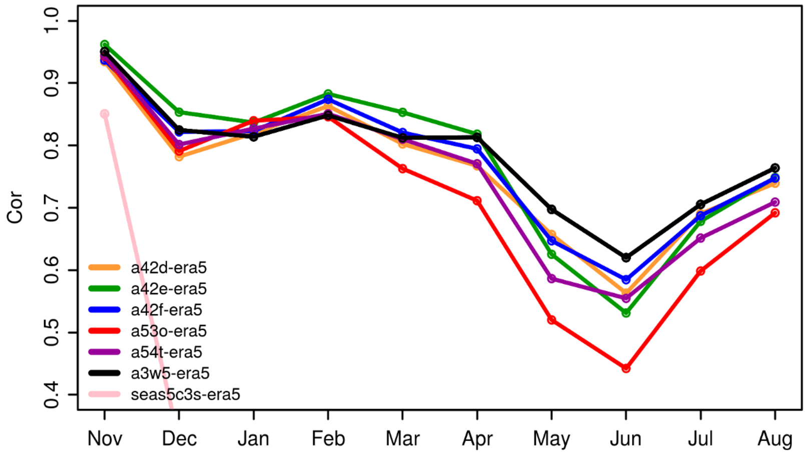




ACC Niño3.4 Index



ACC Labrador Sea SST Index



A. Santos, V. Lapin, A. Carreric, P. Ortega, F. Doblas-Reyes

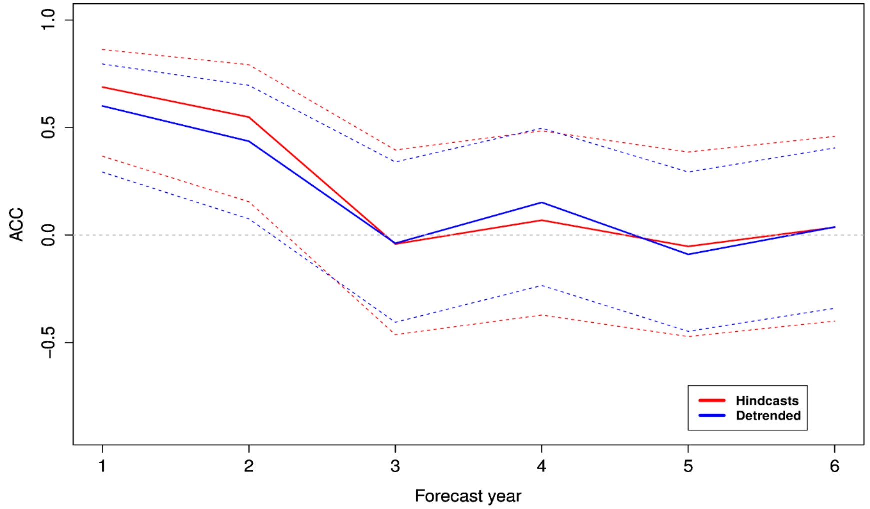
A first decadal hindcast of carbon cycle with EC-Earth-ESM

EC-Earth-3.3-CC (emission driven)
Reforecast period: 1980-2020

Ensemble size: 10 members
Forecast length: 7 years

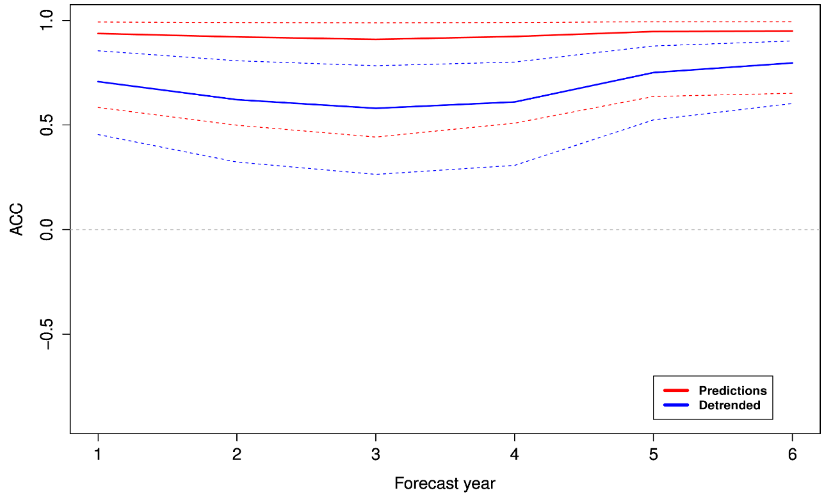
Ocean initialization: As in new EC-Earth3-GCM system (only physics assimilated) → 3 cycles to get present CO2 uptake
Land initialization: Offline land-surface reconstruction with LPJ-GUESS → forced with ERA20C/ERA5 (prior/after 1950)

Skill of global <u>land</u> CO2 flux anomalies



Land C flux skill is limited to 2 years lead time

Skill of global <u>ocean</u> CO2 flux anomalies



Ocean C flux skill is high and remains significant

E. Tourigny, J. Acosta Navarro, R. Bernardello, V. Sicardi,
E. Exarchou, V. Lapin, M. Donat, P. Ortega